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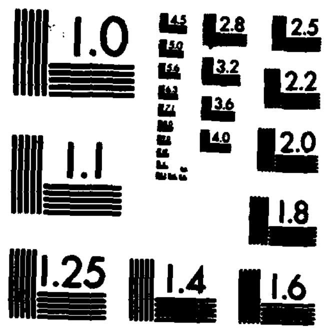


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Integrated Navigation Systems -- Where Are We Headed?

The relentless penetration of technology and the explosion of information collecting and processing systems is rapidly becoming a challenge to users of modern navigation techniques. The most positive outlook is that development of new and improved integrated and synergistic navigation systems will result to take advantage of the common objective of all navigation systems -- accurate and quick determination of ship position.

This paper traces briefly the rapid growth of technology and the information revolution. Navigation in the past -- and even now -- has involved paper charts, coupled with celestial and visual methods. Currently, we are experiencing growing capabilities to figure navigation problems quickly using hand-held calculators, portable computers, and to position ourselves worldwide with such systems as Omega and the Global Positioning System. → cont


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To cope with excessive information overload, there is a need to integrate into a simple system changing status of events affecting ship operations using such diverse data elements as weather, fuel consumption rate, ship position and track, display of essential chart features, and Notice to Mariners changes. The integrated navigation system, a subsystem in a comprehensive ship control system, will have to be capable of allowing the mariner to selectively handle the data mass available. The objective of the paper is to stimulate discussion in actual and conceptual approaches to integrated navigation systems.

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# INTEGRATED NAVIGATION SYSTEMS ---WHERE ARE WE HEADED ?

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Deputy Director

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## ABSTRACT

The relentless growth of technology and explosion of information collecting/processing systems are a challenge to modern navigators. The outlook is for development of integrated and synergistic navigation systems which will result in quick, accurate determination of ship position.

This paper investigates the effect of technology and the information revolution on navigation. Navigation in the past and now has involved paper charts with mostly manual methods. We are now experiencing growing capabilities to solve navigation problems quickly using automated methods and position ourselves with such systems as Omega and GPS.

To cope with information overload, there is a need to integrate the information affecting ship operations using such diverse data elements as weather, fuel consumption rate, ship position and track, display of essential chart features. The integrated navigation system, a subsystem in a comprehensive ship control system, will have to be capable of allowing the mariner to selectively handle the data mass available.

# INTRODUCTION

Recently, much has been written about the Information Age. This age, which is being brought on by the onrush of automation, is thought by many to be of revolutionary proportions. Futurists, looking into the past and future, have postulated that the coming of the Information Age will be as traumatic to society as was the change from the Agricultural Age to the Industrial Age. In fact, Alvin Toffler, a well-known futurist, expects a quantum leap forward for mankind and maintains that we are "engaged in building a remarkable new civilization from the ground up." He calls this "The Third Wave." (The first two waves were the change from hunting and gathering to agriculture, followed much later by the Industrial Revolution.)[1]

Each wave has taken progressively less time to accomplish. The Industrial Revolution, for example, required took about three centuries to achieve massive changes. The next age will be upon us about much more quickly because of the compression of time caused by technology. We have already seen remarkable changes in the past fifteen years. One needs only to think back to 1969 and recall what his/her expectations were at the time for the next fifteen years. We were still in the punch card era and very expensive electronic calculators able to complete simple functions were only just appearing. Many of us dreamt about computer terminals and interactive programming, but I venture to say that few had any real comprehension of where we would be now. Now look at what is available to

us. The one mega-bit chip is a reality and there are portable microcomputers which easily fit into an attache case. What might we expect in the next fifteen years (ie., the turn of the century)?

We now find ourselves in the middle of this exciting age with change going on almost faster than we can accommodate it. It has been said that the amount of knowledge which mankind must learn doubles every seven years. If this figure is correct, then this predicument presents staggering problems for the future. How will all this information be handled ? We can at least assume that the thrust of the 'Information Age' will shift from the question of information supply to information selection. The emphasis will be on how to filter and use effectively the masses of information. To quote John Naisbitt from his best seller, Megatrends:

"We are drowning in information, but starved for knowledge."[2]

## CURRENT NAVIGATION

Present day navigation is in a state of flux with the onset of the new Global Positioning System which will give us unprecedented accuracies worldwide. With NAVSAT and Omega, the open ocean navigator is able to transit the world's oceans with considerable success. It is when the navigator nears land that he has to revert to older means of navigation.

As one nears land, one must break out come the charts and the whole business of navigation shifts to positioning the ship more with respect to the channels and aids to navigation. Early in the journey or certainly before landfall is made, the necessary charts are selected and current

Notices to Mariners data are entered. The vessel's position is determined from one or more methods, including celestial, and plotted on a coastal chart. Usually several methods are used and the positions are compared. It is here that the chart serves a major function of providing a convenient collection medium for position comparison and validation. Here, also, is a potential for some error, that is, when one translates information from the source method onto the chart.

As one begins to close in on land or dangerous inlet, it is necessary to pay closer attention to the chart which is beginning to become cluttered with information. First, there is the charted information. Then the mariner begins to draw lines of bearing, distance arcs, lines of position and other information in an effort to get the best possible positional information from the plotted triangle of error. The closer one comes to the danger or land, the greater the concentration on the chart and the more demanding are the external distractions vying for the navigator's attention.

Must the mariner use such a cumbersome system? The answer is that the chart provides the best means for consolidating all of the navigation information in one place. Needless to say, matters would be less stressful and navigation no doubt much safer if all or most of the above data could be displayed on one piece of equipment.

## AN INTEGRATED NAVIGATION SYSTEM

What is needed is an integrated navigation sy[illegible] which will take the inputs from the various navigation data sources and combine them into one easily read presentation. Such an integrated system would result in 'synergism', a key conceptin the Information Age vernacular. What does it mean? Generally, it is the result arising from cooperative actions of two or more constituents which produces a total effect greater that the sum of the constituent parts. The best example involvinga navigation is the advantages that developfrom the overlaying of (or projecting through) aradar image on a navigational chart, which displays the vessel's position. The result of such juxtapositioning of information is the ability to navigate off the chart while monitoring external activities also displayed at the central console.

When one considers the automated navigation systems available aboard 757/767 aircraft, it is difficult to understand why they are not installed on ships. A ship is big business. Operations are becoming more costly every year and each hour's delay costs a significant sum of money. Why then, aren't there more computers to handle basic navigation maneuvers? More often, one finds microcomputers aboard ships to handle other functions as cargo distribution, status of liquids in tanks, messing and pay. When such computers are aboard, there is every reason to extend them to integrate all the shipkeeping and administrative functions. A system would constitute a Ship Control and Administrative System and could

consist of numerous subsystems as shown in Figure 1. The beauty of this master system is that information from any of the subsystems would be available through other subsystems for multiple users.

Consider, for instance, the navigation and engineering subsystems which could combine in the central processor in providing a current evaluation of fuel usage. The anticipated arrival times, intracted from the navigation subsystem, could be programmed into schedules for watch standing or messing requirements. Remote stations throughout the ship would enable officers and crew to access the computer in either interactive or passive modes. One such advantage will be the availability to the Commanding Officer/Master of all important navigational information in his cabin at any time.

A major computer/display system, as described, will have to be highly reliable to preclude loss of data and to ensure the capability to perform critical functions. this kind of reliability has been developed using space-age quality control concepts. An effective solution is to triplicate major components for critical subsystems. The output of all three systems is monitored, and when one varies from the other two, an alarm flag is flashed and the erratic subsystem bypassed or replaced. Modern network systems are now designed with central busses allowing functional tasks to be transferred throughout the system.

In this paper, we shall limit ourselves to the subsystem which handles navigation tasks. Conceptually, the Integrated Navigation System comprises this subsystem and could also consist of several sub-subsystems, such as one that processes electronic chart information, weather, and collision avoidance. Each subsystems would link into the Integrated Navi-

gation System where the mariner would be able to manipulate and control the information necessary to safely navigate the ship. The paper hydrographic chart, as we know it today, will probably be supplanted eventually by digital data displayed in a graphic manner on an electronic screen. These electronic navigation charts are one of the multitude of new products being developed as the result of the coming of the Information Age. Concurrently, the legal aspects of electronic displays and magnetic tapes must also be resolved before paper charts, which provide a convenient record of navigation tracks, bearings, etc., can be replaced or forced into a backup role.

The integrated approach of these automated navigation systems is most desirable in situations where the full utilization of outside navigational aids is denied by the environment. In fact, one such system is already being considered by the oil industry in the Canadian Arctic, where a need exists to combine navigational information with the latest weather and ice information in order to operate more effectively in the hostile environment. With these conditions, it is of critical importance for the navigator to be able to match radar with a charted depiction of land features. Techniques of this typeare of great value to navigators, especially in waters where the ice pack makes voyages seasonably limited.

Any aspect of the maritime industry which requires some knowledge of bottom topography and the water column will benefit from electronic charting. As implied above, the electronic chart may not look the same as the paper chart we know today. Certainly there will be plan views, but with the growth of three-dimensional displays for Computer Assisted

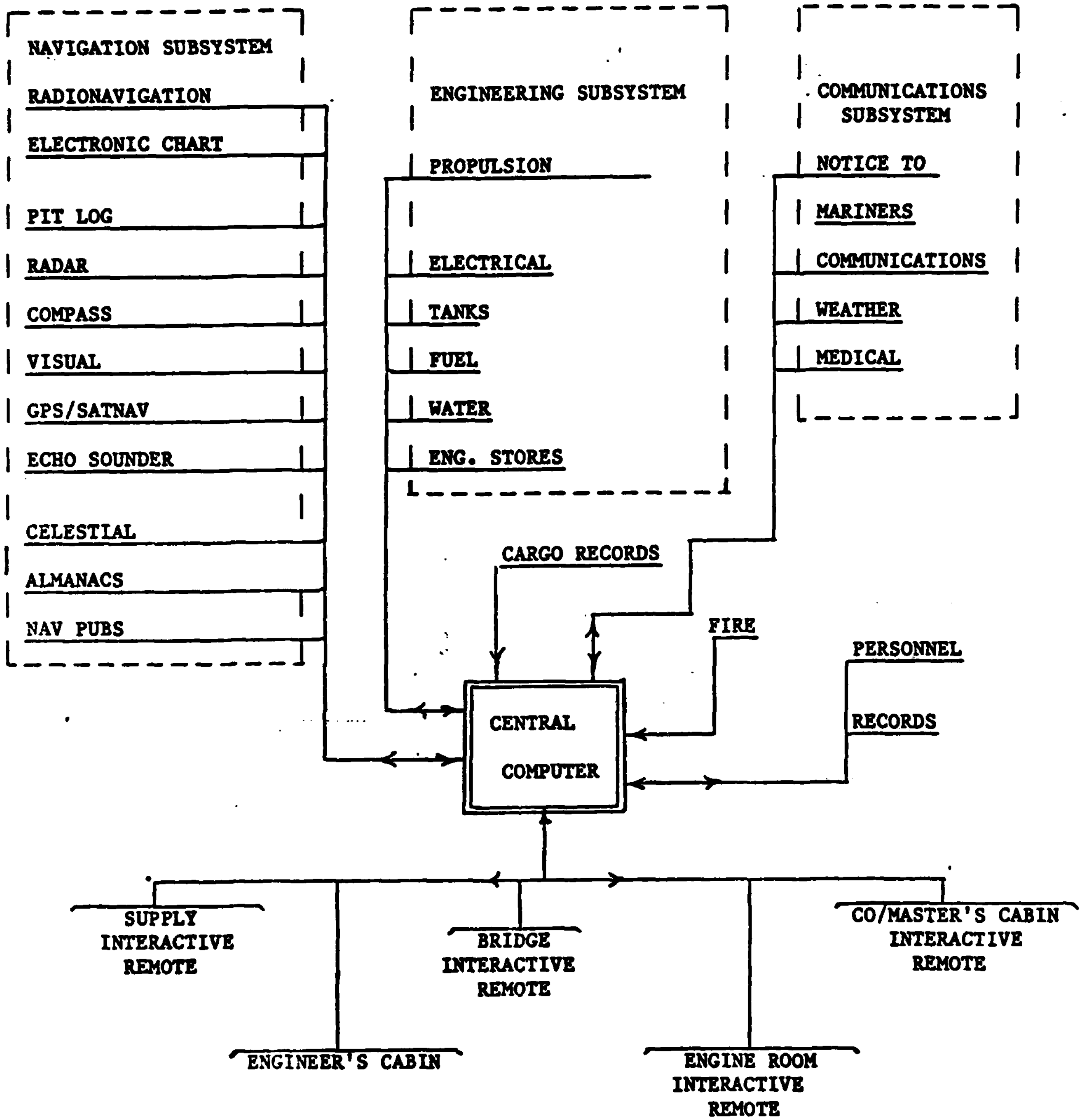


FIGURE 1. LINE DIAGRAM OF INTEGRATED SHIP CONTROL SYSTEM

Design-Computer Assisted Manufacturing (CAD-CAM), it will not be long before these may become available for fishermen, dredgers, or submariners to fly over the bottom and avoid danger areas such as natural obstacles, wrecks and pipelines - all of which are specially portrayed. These same types of displays could also provide vital information to mine warfare and submarine forces. These displays might look like that shown in Figure 2.

Two dimensional displays are already being used by fishermen on Long Island Sound and in Japan. Another use could be in hydrographic survey work where presently-held data could be displayed, and real-time surveyed information could be compared after corrected for sound velocity, tide, and hull transducer depth. The advent of the Global Positioning System (GPS) in 1987-88 will greatly expand the possibilities for electronic navigation.

## THE ELECTRONIC CHART

Just as the heart of traditional navigation in pilot waters was the paper nautical chart, so also will the digital tape cassette that drives production of an electronic chart gradually form the centerpiece of an integrated navigation system.

The definition of the electronic chart, for the purpose of this paper, is navigation information which is transmitted or presented in an electronic manner. At a workshop held in October 1983 in Baltimore, Maryland, there was wide-ranging discussion on the exact meaning of an

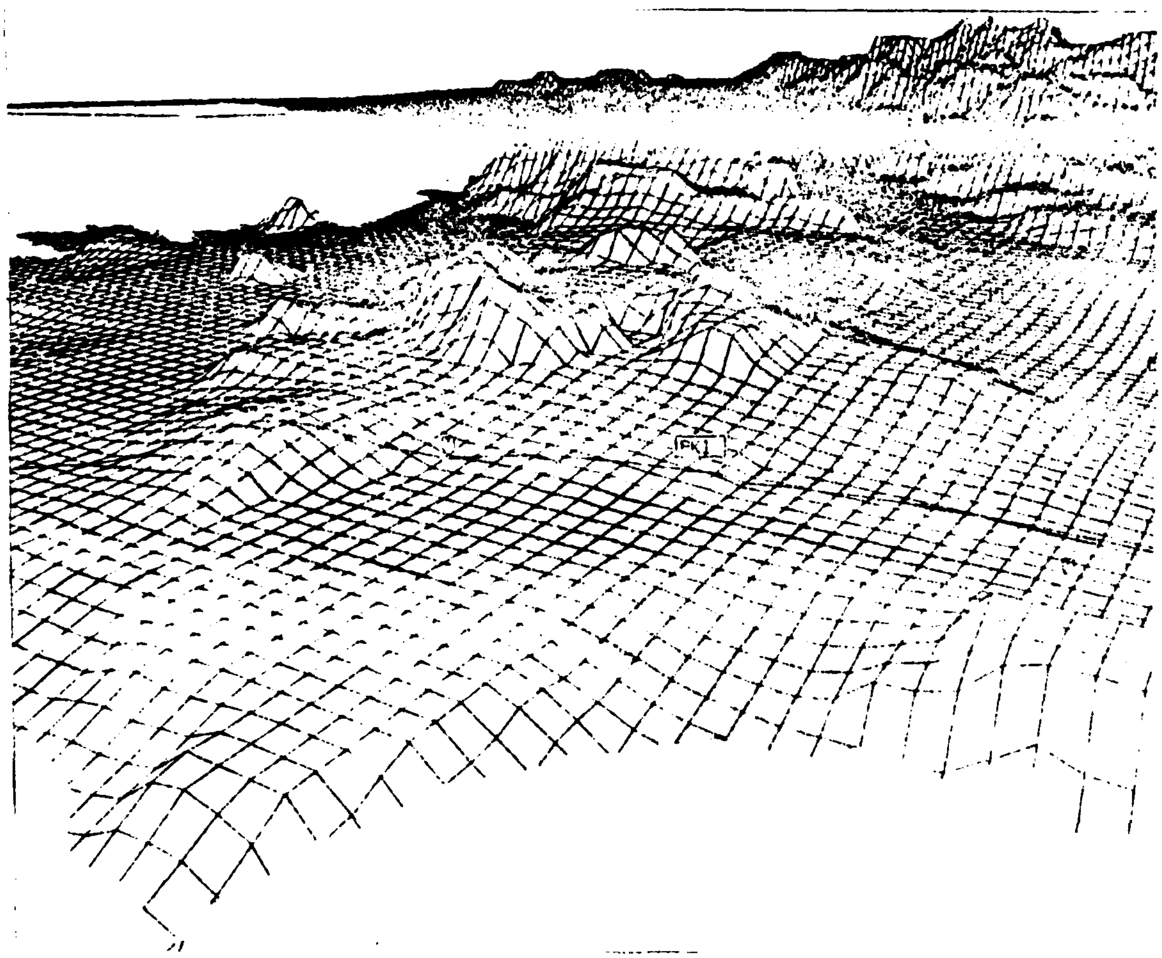

FIGURE 2. PERSPECTIVE VIEW OF THE OCEAN FLOOR

electronic chart. General consensus was that electronic charts must be compatible with radar scene displays. The capability to superimpose radar images on a chart allows great benefits in piloting situations and gives the integrated navigation system its greatest synergism. Because we are combining two presentations into one, there must be constraints on data density, format, colors, and allowable amount of textual information.

Electronic displays are presently limited by the relatively small size of the cathode ray tubes available. Future advances in large screen technology will allow significant improvements in presentation. Hughes Aircraft is presently working on a Plotter and Combat System (PACS) display for the Navy. The PACS will utilize a liquid crystal light valve to project an image on a 0.58m x 0.79m plotting table from below. This technology has resulted in a display one meter on the diagonal with an anticipated two meter diagonal screen in late 1984. It should not be long before we shall see thin (about 3 cm thick) screens using electroluminescent technology. One such advance may come through the use of the currently-available liquid crystal plasma screens.

Because the resolution of display systems is coarser than the paper product, chart symbols will have to be modified to be more suitable for electronic display. The use of generalized depth contours, rather than spot soundings, will allow for a relatively clutter-free chart and the contour interval decisions will be made by the mariner, who may require a given isobath to be emphasized to draw attention to some specific ship

draft or keel depth limits. With the ability to select the types of information displayed on the screen, the mariner may avail himself of the great potential for presentation of numerous categories of data.

The minimum data which should be available to the electronic chart user are:

-Shorelines, including piers, bridges and other cultural details necessary for safe navigation.

-Bathymetry.

-Shoals, dangers or selected isobaths.

-Channels or traffic separation schemes.

-Navigational aids, including buoys, lights and marks.

-Radar and visually-significant features and topography.

Similarly, the opportunity for clutter will be great. Electronic displays can be rapidly overwhelmed with data. It will be the decision of the mariner as to what is shown. One function which is presently being considered by a manufacturer is the ability to cause lights and lighted buoys to flash on the screen with the same periods and colors as the actual lights themselves. With the selectivity functions, the user might "turn off" these lights to prevent distraction during daytime navigation. At the same time, such flashing lights preclude much textual information from being included on the chart.

With all this information on the screen, the mariner will be able to meaningfully pick and choose what will be displayed. Such a function is easily accomplished on an electronic chart. For instance, a hypothetical tug skipper is making his way up New York Harbor. He has a tow which

draws 25 feet. He has already ordered his system to draw the limiting depth contour for 30 feet, inside of which he will not want to venture. Suppose there is a small patch of water in the middle of the channel which is shown to be less than 30 feet. To steer around this would require the tug and tow to take a more heavily trafficked channel and lose 45 minutes of transit time. The skipper need only query the navigation subsystem to give him the spot depths for that patch. Tidal information might be available in the system from either digital tables or from a telemetered signal from the local tidal monitoring station similar to that run by the NOAA in New York City. If the skipper is convinced that he can make it over the shoal, he might make that decision and save valuable time.

The navigational chart must be current to be of use to the professional mariner. The electronic chart concept offers an outstanding solution to the problem of keeping products up to date. With paper charts, the user is tied to the reprinting cycle and hand corrections based on weekly Notices to Mariners. With the electronic chart, corrections will be made automatically through use of direct input from the Automated Notice to Mariners System. DMA is making Notice to Mariners information from its computer available directly to ships by way of Inmarsat and modems. An integrated navigation system could be programed to take that information direct and make the chart corrections.

## OTHER FEATURES

Some of the additional functions which could be usefully generated by the integrated navigation system and overlaid on the electronic chart are the plotting of own ship's and other vessels' tracks (course, speed and closest point of approach), way points, danger bearing lines, set and drift calculations, and similar navigational information. Such information, plus collision avoidance data, would be of extreme value in restricted waters. The output from a shore radar might be transmitted to the ship to enable it to "see" around bends. The integrated navigation system will accept all manners of navigational information from such sources as GPS, electronic radionavigation signals, and more conventional visual methods and integrate them. The integration would allow synergistic interaction and comparison of the information to obtain the very best "fix" on a real time basis. The advent of artificial intelligence will allow the machine to combine all information for the navigator and present a weighted average fix as well as monitor each of the signals for errors. It should even monitor itself for internal problems and errors.

In the case of piloting, that is, navigation in restricted waters, the navigation subsystem will be able to perform its most useful navigational function by combining the piloting chart with ship's position and a radar overlay. Aboard today's ships, the piloting officer must split his attention between the radar screen, the chart (for both plotting and

course determination), and visual observation. Combining so many conflicting, but equally important, tasks into a central display will relieve the officer of many distractions.

As noted above, the synergistic aspect makes it all worthwhile because there is much more to be gained from such an integration than just bringingtwo functions together. Radar is used extensively in navigation, but presently it must be observed, measured and then transferred (radar data) manually to the chart. With the integrated electronic chart, this will be accomplished automatically with comparison of radar images of the land being matched with charted features.

On the open sea, the integrated navigation system will use positioning information gleaned from many sources to combine with other related information (such as fuel state, weather and ice reports) to plot out a recommended course and even steer the ship. Such a use could result in meaningful savings in passage times.

## CURRENT INTEGRATED NAVIGATION SYSTEMS

There are several examples of integrated navigation systems now under development or on the market. While they might appear rather innovative, their impact is only just being felt. Some examples of these systems are:

1. Bowditch Navigation Systems Corporation's <u>Bowditch Navigator</u>. It displays a microform image of a paper chart on a screen which is driven by radiolocation system inputs. It is used for navigating

vessels in a harbor. The Bowditch Navigator allows for an integrated approach by the incorporation of additional functions, such as way point identification and location of vessel with respect to intended track.

2. The Command Display and Control System (COMDAC), being developed for the U.S. Coast Guard by Sperry, is an integrated navigation, collision avoidance and tracking system which displays and electronic chart on a cathode ray tube (CRT). This chart provides generalized features, such as shorelines, danger bearings, channels and buoys. The system will combine navigation with tracking and recording capabilities to be used in multiple roles including the tracking and interception of lawbreakers, and the documentation and recording of the circumstances for use in any arising litigation.

3. Furuno, U.S.A., Inc. has two video track plotters which give color readouts of ship's course and navigation marks. Many types of information are available, including way points, alarms and fix marks.

4. The Hydrofoil Collision Avoidance and Tracking System (HYCATS), developed by Sperry for the U.S. Navy, is presently deployed aboard U.S.S. PEGASUS (a hydrofoil gunboat). It is similar to COMDAC, but is designed more for high speed navigation and collision avoidance. It uses either a generalized electronic chart or a televised paper chart as its base and combines it with radar into an integrated display.

5. Japan Radio Co., Ltd. has brought out the SNA-80 Total Navigator II which graphically displays ship's course, a chart and ARPA data. It also has an autopilot and can track other ships, navaids and landmarks.

6. Navigation Sciences Corporation's VIEWNAV provides the user with an electronic chart over which a ship symbol is positioned in accordance with a differential LORAN C signal. The chart presentation overlays the raster radar return at scale. The display is designed such that the radar return from the land and charted features is masked out by these charted features. For example, a new pier, installed since digitization, would appear in a characteristic red color protruding from the digitized land color of yellow. An added capability is realized by the independence of the radionavigation data from the radar, thus allowing the user to check the two systems against each other. There are a number of integrated features such as way point location and location with respect to intended track. The VIEWNAV electronic chart has a presentation which is very much like a standard chart.

7. NavVue, Incorporated's NCD-39 navigation computer display unit displays monochrome CRT images of a line chart digitized by the owner. It has grids, pre-course setting displays, current position and several other options. It is a very inexpensive, yet simple system.

## SUMMARY

The mariner of the future will have more than enough information available to him. The problem will really be how to separate the meaningful information from that which is less usable, but which should be available if needed. Technology is speeding along at an unprecedented rate, and there can be no doubt that vastly increased computer memories and speed in the future, with artificial intelligence will greatly improve real-time navigational information to the mariner.

By integrating the numerous navigational data flows into one system, where they can be evaluated and combined, this wealth of information can be presented in a consolidated and easy to understand form. A mariner, when piloting his ship, cannot spend a great deal of time trying to figure out his position. His attention should alsobe turned elsewhere, to the tactical problem, if you will. He will require a clear and concise picture combining a chart with own-ship's position and radar. Other data may be called up at will, such as other vessels' tracks and tidal data.

As was seen in the last section, there are many systems available which are moving towards the integrated navigation system concept. None is yet complete, but a start has been made. The "Information Age" is here, now, in the maritime community.

1. Alvin Toffler, "The Third Wave," from *Through the 80's, Thinking Globally, Acting Locally*. Ed. Frank Feather. (Washington, D.C.: World Future Society, 1980), page 9.

2. John Naisbitt, *Megatrends* (New York: Warner Books Inc., 1982), page 24.

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